

PRODUCTION AGRICULTURE

Economic and Agronomic Assessment of Deep Tillage in Soybean Production on Mississippi River Valley Soils

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ABSTRACT

Using deep tillage to alleviate the adverse effects of deleterious soil physical properties has been tried many times. Consistent economic returns have been reported for in-the-row subsoiling of loamy sand and coarser soils and for deep loamy soils where the subsoil slit bisects the water flow channel during rainfall events where there is runoff. Recent reports of yield responses on clayey soils and silt loams led to a reassessment of subsoiling of these soils in Arkansas. A randomized complete block design was conducted at four locations with tillage treatments of conventional shallow, deep chisel, subsoil dry, subsoil wet, subsoil at 45° to planting direction, and paratill. Plots were harvested for grain. Economic analysis was performed using the Mississippi State Budget Generator (MSBG). The machinery complement was commensurate with that found on farms in the region. Net returns above total specified costs (NRAT) rather than above direct costs were calculated to reflect the decision framework of a producer. A profitable yield response was obtained from subsoiling in dry soil on deep alluvial clayey and silt loam soils but not on the thin loessial silt loams. Net returns to subsoiling wet were not significantly higher than those to conventional shallow tillage. Tillage with a chisel plow as deep as it could be operated (approximately 15 cm) was not a substitute for subsoiling because yield responses from deeper tillage were not comparable. The 45° subsoiling in dry soil tended to be superior to all other tillage treatments.

DEEP TILLAGE TO LOOSEN SOIL for the purpose of promoting infiltration, internal water drainage and storage, soil aeration, increased rooting depth, and increased rooting density has appeared attractive for many years. Many deep tillage studies have been conducted, but only a low percentage of them have been reported. The primary reason for this low reporting rate is the lack of yield response to deep tillage.

Deep tillage responses can be classified according to soil characteristics. Large, consistent yield responses are obtained in soils that are deep (i.e., no root restricting naturally occurring horizons in the control layer—the top 70 cm) and have a nonplastic texture (usually loamy sand or coarser) at a 0- to 15-cm or 30-cm depth. These nonplastic soils usually respond to in-the-row subsoiling (Batchelor and Keisling, 1982) that provides a continuous low-density slit for roots to penetrate into the sub-

soil. Planting of the crop over this low density slot is critical. These soils occur in the USA, primarily in the Coastal Plains, and in other regions to a minor extent (Buol, 1973).

In the Mississippi River alluvium region, for example, yield responses to deep tillage were found for cotton (*Gossypium hirsutum* L.) on deep silt loam or sandy loam soils (Spurgeon et al., 1978; Tupper and Spurgeon, 1981). This response differed from that of nonplastic soils in that no response was obtained from in-the-row subsoiling. The best results were obtained from deep tillage in the fall, which left low-density slits that geometrically intersected the low points between old seedling rows. The low points concentrate runoff water during high intensity rainfall events. Thus, it appears that deep tillage here was promoting infiltration and subsequent soil water storage in these deep silt or sandy loam soils. More recent studies (Keisling et al., 1998) using a paratill on a bedded system tended to provide consistently higher cotton yields than conventional tillage practices.

No consistent soybean [*Glycine max* (L.) Merr.] or cotton yield increase from deep tillage on clayey textured soils was reported until 1991 (Wesley and Smith, 1991). Consistent responses were obtained on a Tunica clay to fall subsoiling when the soil was dry. The clay soil (when subsoiled under these dry conditions) will break into clods that are sometimes as large as 70 by 30 cm. These large clods can result in a very rough surface, which some growers want to immediately smooth. Because the soil is very hard, this smoothing can result in the loss of an economic gain obtained from the subsoiling. The profit potential from subsoiling these clayey soils located in the Mississippi River alluvium was comparable to that obtained from irrigation (Wesley et al., 1993).

On loamy textured soils that have a naturally occurring root and water restrictive horizon in the control layer, yield responses have been found from deep tillage in the fall when the soil was dry and there was an excess of soluble salts (Pearce et al., 1999). No other reports of yield responses to deep tillage were found for these soils.

The study reported here was initiated with the objectives of (i) quantifying the yield responses on clayey soil types other than those described in the literature, (ii) examining the responses on soils with textural and profile characteristics other than deep clayey soils, and (iii)

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Abbreviations: MSBG, Mississippi State Budget Generator; NRAT, net returns above total specified costs.

Table 1. Location and soil series at various locations where tests were conducted.

Location			
Place	Longitude	Latitude	Soil Series
Dansby, AR	90°39'W	34°52'N	Alligator-Earle-Sharkey Clay†
Dansby, AR	90°40'W	34°51'N	Dubbs-Dundee silt loam‡
Moro, AR	91°00'W	34°53'N	Grenada silt loam§
Pine Tree, AR	90°57'W	35°08'N	Calloway-Henry silt loam¶
Marianna, AR	90°45'W	34°46'N	Alligator clay
Keiser, AR	90°05'W	35°46'N	Sharkey silty clay

† Very-fine, smectitic, thermic Chromic Dystraquept; clayey over loamy, smectitic, acid, thermic Vertic Epiaquept; very-fine, smectitic, thermic Chromic Epiaquept, respectively.

‡ Fine-silty, mixed, active, thermic Typic Hapludalf; Fine-silty, mixed, active, thermic Typic Endoaqualf, respectively.

§ Fine-silty, mixed, active, thermic Glossic Fragiudalf.

¶ Fine-silty, mixed, active, thermic Glossic Fragiudalf; coarse-silty, mixed, active, thermic Typic Fragiqualf, respectively.

performing economic analysis to determine the profitability of deep tillage operations.

MATERIALS AND METHODS

Agronomic

Deep tillage studies were begun in the fall of 1994. The sites selected for the studies and their characteristics are shown in Table 1. Tillage treatments were: (i) conventional shallow tillage (disked, chisel-plowed, or field-cultivated to 10 cm deep) twice in late winter or early spring to prepare a seedbed; (ii) deep chiseling in the fall to a depth of approximately 15 cm when the soil was dry [less than approximately 11 or 20% water on a volumetric basis (Table 2) for silt loams and clays, respectively]; (iii) subsoiling in the planting direction after harvest when the soil was dry with a hyperbolic subsoiler (shanks 50 cm apart) to a depth of approximately 35 to 45 cm. There was no attempt to position the seedling rows directly above the subsoil slots; (iv) same as the third treatment but at a 45° angle to the seedling row direction or field slope; (v) same as the third treatment but performed in late winter or early spring when the soil was moist (note changes in soil water content in Table 2); (vi) same as the third treatment, except a paratill was used; and (vii) same as the third treatment, except a straight shank subsoiler was used that had a winged tip 12.5 cm to 17.5 cm wide. The treatments were arranged in a randomized complete block design with 8 to 10 replications. The alleys between plots were 9 m wide to provide ample room for tillage implements to reach the desired operating depth before entering the plot and to keep machinery out of adjacent plots when leaving the plot and turning. The plots were 15- by 3.8-m rectangles, except for the 45° treatment, which was 15 by 11.4 m to allow for turning on the sides without trafficking adjacent plots. All of the treatments were not performed at every location, owing to the availability of equipment. To test other equipment, an auxiliary experiment was done at Pine Tree, AR with treatment no. 1, 3, 6, and 7, arranged in a randomized complete block with four replications.

Because of the erratic nature of past responses to subsoiling, two additional experiments at Keiser on a Sharkey silty clay were located in fields with different cropping and tillage histories than the main experiment. These experiments used only the first and third treatments arranged in a randomized complete block with four or eight replications and were conducted only in 1995.

Soil was sampled in late winter or early spring of 1995 at two locations. The samples were taken from a random location

Table 2. Soil water content of deep tillage experiments at two locations in early spring and late summer, 1995.

Deposition Soil series Treatment	Soil classification							
	Alluvial Alligator–Earle–Sharkey				Loessial Calloway–Henry			
	C†	SS‡	C	SS	C	SS	C	SS
Time of year	Spring		Summer		Spring		Summer	
Depth, cm	Volumetric soil water content							
	cm ³ cm ^{−3} × 100							
0 to 15	19.1	27.1	18.7	24.4	17.9	20.2	7.6	9.1
15 to 30	37.4	37.6	30.4	28.7	28.0	27.2	11.1	11.4
30 to 60	44.2	42.4	35.2	35.5	36.3	35.6	20.7	28.6
60 to 90	43.4	38.8	35.1	33.9	28.6	33.8	19.9	20.8
90 to 120	33.4	43.8	34.5	34.2	—	—	—	—
Total stored§	cm							
Water removed¶	45	48	39	40	27	28	15	24
	6	8			12	4		

† Conventional shallow tillage treatment.

‡ Subsoil with a parabolic subsoiler.

§ Total stored water is the sum of the depth increments multiplied by the volumetric soil water content.

¶ Water removed is the difference in total stored water for a tillage treatment between the spring and summer measurements.

in each plot. Two 15-cm-diam. bucket augers were used to obtain the sample for the volumetric water content. A regular bucket auger was used until its prongs reached the bottom of the sampling depth. The sample was then completed with a bucket auger that had a sand point, which allows a precise evacuation of the corners and edges to collect a known volume of soil that is suitable for measurement of the volumetric soil water content. Soil was placed and sealed in tared metal containers, transported to the laboratory, weighed while moist, dried for 2 wk at 105°C, and weighed dry. The weights were used to calculate the volumetric water content (Table 2). Samples were taken again in later summer of 1995 at the R7 (Fehr and Cavendish, 1977) soybean growth stage using a soil sampling tube with an extendable handle.

The early maturing-early planted (EMEP) soybean production system (Heatherly, 1999) was used because this results in later summer or early fall harvest dates. This early harvest is necessary so that deep tillage can consistently be done in dry soil before significant fall rainfall. After tillage, no additional tillage operations were performed until late winter or early spring when normal seedbed preparation activities occur. The seedbed preparation consisted of two passes with a field cultivator to loosen the soil, smooth the ground, and apply and incorporate herbicides where appropriate. Other cultural practices, equipment choices, and farm sizes were commensurate with Arkansas Cooperative Extension Service observations (Brown and Windham, 1997).

The soybean yield (adjusted to 13% moisture) was calculated from strips harvested with a small-plot combine from the center of each plot. Yield data were analyzed statistically using the General Linear Models (GLM) procedure of SAS (SAS Inst., 1989).

Economic

Economic analyses are based on enterprise budgets generated by the MSBG (Spurlock and Laughlin, 1992). An enterprise budget was generated for each year, tillage treatment, and location combination utilized in the study. Economic analysis that addresses the issue of farm and field size was considered beyond the scope of this study. Due to the number of replications in the experiment, the MSBG was used to calculate only direct and fixed expenses while net returns were calculated using a spreadsheet. A soybean price of \$0.246 kg⁻¹

was used to calculate the gross receipts, representing a 5-yr (1993–1997) average of the statewide soybean price, and was based on values reported in the 1996 Arkansas Agricultural Statistics (Arkansas Agric. Statistics Serv., 1997). This average price was used to eliminate any market effects that were due to years with abnormally high or low prices. The input prices, included in the version of the MSBG issued by the Arkansas Cooperative Extension Service in 1999, were used for field operations (CES, 1999).

For budgeting purposes, all of the treatments utilized a machinery complement consisting of an 8.9-m field cultivator pulled by a 149-kW tractor, a 6.0-m grain drill pulled by a 108-kW tractor, a 14-m broadcast sprayer pulled by a 108-kW tractor, a 3785-L water tank pulled by a medium duty pickup (approximately 2.1 and 6.1 Mg hauling and towing capacity, respectively), a 2.4-m furrow ditcher pulled by a 108-kW tractor, and a 6.0-m soybean combine. The fall and spring subsoiled treatments also utilized a 3.6-m seven shank subsoiler. The deep chiseled plots used a 5.1-m chisel plow and the paratill treatments utilized a 4.5-m six shank paratill implement. All of the deep tillage implements were drawn by 168-kW tractors. Commensurate repair and maintenance, fuel, depreciation, and opportunity cost estimates on equipment were provided through the Arkansas Cooperative Extension Service (Brown and Windham, 1997).

The same statistical procedure (where appropriate) was used for analysis as was outlined in the agronomic section. The NRAT rather than the net returns above direct costs were reported due to the time frame decision makers would use to make implement choices. The decision regarding the use of subsoiling should include any changes in the fixed cost (e.g., additional equipment) compared with conventional tillage practices.

Break-even and sensitivity analyses were conducted to gain a broader perspective of the economic implications of the various tillage, planting, and herbicide combinations. Break-even analysis was conducted for prices and yields that were above the total specified expenses. Sensitivity analysis for the NRAT was conducted using soybean prices that varied by as much as 25% from the 5-yr average price of \$0.246 kg⁻¹. Additional analysis was performed using the input costs of the additional deep tillage operations.

RESULTS AND DISCUSSION

Agronomic

The amount of stored water plays an important role in the crop yield response (Barnes et al., 1971). Note

that the clayey soil has essentially twice the stored soil water as the loessial silt loam (Table 2). Thus, if a plow pan is removed that restricts downward rooting, there may be much more water for the plant to potentially extract in the alluvial soils than the loessial soils.

From the above deep tillage studies conducted, the yields of five sites (Dubbs–Dundee, Alligator–Earle–Sharkey, Grenada, and two Calloway–Henry) are reported in Table 3. From Table 1, the study on Alligator clay at Marianna, AR was discontinued due to late spring flooding from Mississippi River backwater in 1995 and 1996. The two extra 1995 sites at Keiser on Sharkey clay (not reported in Table 3) showed significant ($\alpha = 0.05$) yield increases of 436 kg ha⁻¹ at one site and no response on the other. The three Sharkey clay sites at Keiser confirmed that deep tillage can result in erratic responses. The two extra sites were discontinued to concentrate on the remaining Sharkey site where a significant response was also obtained.

The treatments were selected to reflect current shallow tillage as the conventional method. Most farmers have a chisel plow, and many believe that it will plow deep enough to be an equivalent to subsoiling. They would prefer to use the chisel plow rather than the subsoiler because the chisel plow can be pulled in excess of 9 km h⁻¹. The usual speed for the operation of a chisel plow would be about 13 km h⁻¹ compared with about 6.5 km h⁻¹ for a subsoiler. In this test, the chisel plow was lowered until the tractor would not move and then raised until most of the wheel slippage ceased.

The years had a highly significant main effect but no significant year $\times$ tillage treatment interaction (as determined by Fisher's *F*-statistic). As a result, the yields are averaged across years and presented as main effects for the tillage treatments (Table 3). Yields were higher for all alluvial soils than for loessial soils. Also, the yields on alluvial clayey soils were, on average, greater than those on alluvial silt loams. Yields at the two clay locations ranged from 2398 to 3488 kg ha⁻¹ while yields on the Dubbs–Dundee silt loam complex ranged from 1893 to 3643 kg ha⁻¹. Where implemented, subsoiling relatively dry soil at a 45° angle to the row direction either showed the greatest yield response or was not measurably different from the greatest yield response obtained.

Table 3. Average soybean yields for all locations.

Deposition Soil series Years	Soil classification					
	Alluvial			Loessial		
	Dubbs–Dundee	Alligator–Earle–Sharkey	Sharkey	Grenada	Calloway–Henry	
	1995–1996	1995–1996	1995–1997	1995	1995–1997	
	kg ha ^{−1}					
Conventional	1890c*	2400b	3030bc	1830a	1230bc	1280a
Deep Chisel	2250bc	2630b	2980c	1830a	1380ab	–
Subsoil Dry	2450b	2840a	3420a	1870a	1210bc	–
Subsoil Dry 45	3640a	2980a	3490a	–	1430a	–
Subsoil Wet	2420b	2630b	3260ab	1930a	1190c	–
Paratill	2410b	2950a	–	1730a	–	1220a
Winged Subsoil	–	–	–	1950a	–	1260a
LSD (0.05)†	369	358	245	228	166	247

* Numbers in the same column followed by the same letter are not significantly different at the 0.05 level of significance according to Duncan's new multiple range test.

† The LSD value is provided for readers interested in comparing two treatment alternatives. For this particular comparison, the LSD criterion is the preferred separation statistic.

The yield response to deep tillage in dry soil was obtained on both alluvial clays and alluvial silt loams (Table 3). Subsoiling wet soil resulted in a yield increase compared with conventional tillage, but the increases were not always significant. Deep chiseling did not increase yields compared with conventional shallow tillage. No significant responses were obtained on loessial soils. One major difference between alluvial and loessial soils is that the alluvial soils are deep and do not have naturally occurring root-restricting pans while the loessial soils are shallow and have naturally occurring root-restricting pans, i.e., clay pans and fragipans. It is hypothesized that disturbance of the shallow plow pans on the loessial soils that restrict rooting or infiltration did not result in sufficiently larger amounts of stored soil water that was extractable by the soybean crop.

Economic

The production costs were greater when subsoiling and deep chiseling were performed in addition to normal conventional tillage (Table 4). This additional operation results in greater labor, fuel, repair, and fixed costs. The paratilling costs were greater than any other tillage practice because of greater repair and fixed costs.

The NRAT were consistently greater for deep tillage

than shallow conventional tillage on alluvial soils, except for the deep chisel treatment on the Sharkey clay (Table 5). Subsoiling dry soil and paratilling resulted in a measurably greater NRAT than the conventional shallow tillage on the Alligator-Earle-Sharkey and Dubbs-Dundee soil complexes. The 45° angle subsoiling was significantly better on all alluvial soils. Subsoiling wet soil was only significantly better on the Dubbs-Dundee complex. Although subsoiling dry soil exhibited a consistently greater NRAT than subsoiling wet soil, the difference was not large enough to be significant. Note also, that the deep chisel treatment did not result in significant increases compared with conventional treatment. This is due to an insufficient yield response. Overall, the 45° subsoiling appears to be the most profitable practice.

Because loessial soils showed no yield response to deep tillage, the break-even analysis was restricted to alluvial soils. On the clay and silty clay soils, the break-even price did not vary greatly across treatments. The break-even prices for all treatments were between \$0.09 and \$0.11 kg⁻¹ (Table 6). The Dubbs-Dundee silt loam complex demonstrated a wider range of break-even prices, from \$0.08 kg⁻¹ for subsoiling dry soil at a 45° angle to \$0.14 kg⁻¹ for conventional shallow tillage. It is interesting to note that in a situation where soybean

Table 4. Average cost information by tillage treatment and soil classification.

		Soil classification				
		Alluvial			Loessial	
Deposition Soil series	Years	Dubbs–Dundee 1995–1996	Alligator–Earle–Sharkey 1995–1996	Sharkey 1995–1997	Grenada† 1995	Calloway–Henry 1995–1997
Input		\$ ha ⁻¹				
Conventional	Seed	35.21	35.21	33.11	–	34.27
	Custom work	5.66	5.66	11.12	–	3.71
	Herbicides	95.60	95.60	96.49	–	66.91
	Labor	11.66	11.54	13.99	–	20.14
	Fuel	10.77	10.63	12.08	–	18.51
	Repair	20.68	20.61	22.26	–	31.31
	Op. interest	6.45	6.45	7.29	–	7.64
	Total direct	185.92	185.55	196.35	–	182.48
	Fixed	61.92	61.75	65.63	–	86.93
	Total cost§	247.84	247.30	261.95	–	261.41
Deep chisel (approximately 15 cm)	Seed	35.21	35.21	33.11	–	34.27
	Custom work	5.66	5.66	11.12	–	3.71
	Herbicides	95.60	95.60	96.49	–	66.91
	Labor	13.76	14.36	16.48	–	22.66
	Fuel	14.01	13.57	15.30	–	21.74
	Repair	24.39	24.31	26.34	–	35.48
	Op. interest	7.24	7.22	8.10	–	8.45
	Total direct	195.43	195.06	206.95	–	193.23
	Fixed	69.53	69.36	73.95	–	95.53
	Total cost	264.97	264.45	280.90	–	288.76
All subsoils‡ (approximately 35–45 cm)	Seed	35.21	35.21	33.11	–	34.27
	Custom work	5.66	5.66	11.12	–	3.71
	Herbicides	95.60	95.60	96.49	–	66.91
	Labor	16.75	16.61	18.95	–	25.55
	Fuel	17.84	17.69	19.00	–	25.82
	Repair	29.92	29.85	31.01	–	40.62
	Op. interest	8.18	8.18	8.90	–	9.46
	Total direct	208.97	208.63	218.56	–	204.90
	Fixed	82.06	81.94	84.31	–	106.80
	Total cost	291.06	290.52	303.49	–	312.11

† Cost information was not available.

‡ Represents an average of costs including subsoiling dry, subsoiling dry at a 45° angle to planting direction, subsoiling wet, winged subsoiler, and paratill when applicable. Paratill costs are approximately \$7-\$10 higher than the other subsoiling techniques due to higher repair and fixed costs.

§ Hauling costs of \$0.006 kg⁻¹ are not included because the yield dependency of this cost does correspond with the purpose of the table.

Table 5. Average net returns above total expenses† from soybeans.

Deposition Soil series Years	Soil classification					
	Alluvial			Loessial		
	Dubbs–Dundee	Alligator–Earle–Sharkey	Sharkey	Grenada	Calloway–Henry	
	1995–1996	1995–1996	1995–1997	1995	1995–1997	
	\$ ha ⁻¹					
Conventional	206.77b*	328.79b	467.05bc	–	30.55a	36.84a
Deep Chisel	275.60b	367.73ab	434.78c	–	46.79a	–
Subsoil Dry	299.13b	394.48ab	519.86ab	–	(16.94)b‡	–
Subsoil Dry 45	587.03a	426.30a	535.37a	–	37.10a	–
Subsoil Wet	293.89b	344.87ab	480.16abc	–	(22.26)b	–
Paratill	282.89b	411.42ab	–	–	–	(25.45)a
Winged Subsoil	–	–	–	–	–	(8.22)a
LSD (0.05)§	88.60	85.90	58.77	–	39.86	NS

* Numbers in the same column followed by the same letter are not significantly different at the 0.05 level of significance according to Duncan's new multiple range test.

† Including hauling costs of \$0.006 kg⁻¹.

‡ Parentheses denote negative numbers.

§ The LSD value is provided for readers interested in comparing two treatment alternatives. For this particular comparison, the LSD criterion is the preferred separation statistic.

prices drop below \$0.14 kg⁻¹ and remain higher than \$0.08 kg⁻¹, subsoiling dry soil at an angle will remain profitable (positive NRAT) while conventional tillage does not, despite the greater production cost of subsoiling. This is due to the yield response obtained by subsoiling. Examining the break-even yields shows that conventional tillage has the lowest break-even yields on all of the alluvial soils (Table 6). Therefore, if yields decrease substantially, there is a point where conventional tillage will be profitable while subsoiling will not. This stems from the fact that conventional tillage has the lowest production cost, and therefore sufficient revenue can be generated to cover these costs at a lower yield.

Market prices were varied up to 25% of the 5-yr average price for sensitivity analysis. Across this range, the NRAT was found to change proportionally more for subsoiling dry soil (especially at a 45° angle) than conventional tillage. This means that the effect of the yield response from subsoiling is magnified with price changes and results in a greater variation of the NRAT with subsoiling when compared with conventional tillage. Producers concerned with temporal net return variability might therefore opt for less variation at the cost of significantly lower net returns (which may in fact lead to losses as discussed above) by choosing conventional tillage over subsoiling.

The sensitivity of the NRAT to changes in the input cost was also examined. This was done by varying the cost of performing the deep tillage operation. The

NRAT was found to be relatively stable in regard to changes in input prices. For example, if a situation arose in which fuel and labor costs both doubled, the relative profitability rankings of the different tillage systems would not change. This indicates that the additional returns from deep tillage are much greater than the additional costs across a wide range of input prices.

INTERPRETIVE SUMMARY

Fall deep tillage (to a depth >30 cm) when the soil is dry on deep alluvial clayey and silt loam soils provides a significant and profitable yield increase. Similar deep tillage on loessial silt loam soils with natural restrictive layers to water movement and root penetration resulted in no yield increase and decreased profits on average. These observations are similar to those found by Barnes et al. (1971). Subsoiling at a 45° angle was found to be superior to other deep tillage options.

Producers, for reasons of faster field speeds and equipment availability, often prefer to use of a chisel plow for deep tillage over that of subsoiling. The results of this study suggest that tillage to approximately 15 cm deep with a chisel plow is not a substitute for deep tillage and may ultimately result in lower returns than conventional tillage.

While conventional tillage was the least expensive tillage treatment used, the yields were generally lower than for other tillage treatments. The yield response

Table 6. Break-even soybean prices and yields above total expenses by tillage treatment and soil classification.

Deposition Soil series Years	Soil Classification					
	Alluvial					
	Dubbs–Dundee 1995–1996	Alligator–Earle–Sharkey 1995–1996	Sharkey 1995–1997	Dubbs–Dundee 1995–1996	Alligator–Earle–Sharkey 1995–1996	Sharkey 1995–1997
	\$ kg ⁻¹			kg ha ⁻¹		
Conventional	0.14	0.11	0.09	1051	989	1046
Deep Chisel	0.10	0.10	0.10	1128	1058	1122
Subsoil Dry	0.12	0.11	0.09	1232	1119	1210
Subsoil Dry 45	0.08	0.10	0.09	1162	1119	1210
Subsoil Wet	0.12	0.11	0.10	1154	1154	1207
Paratill	0.13	0.11	–	1187	1184	–
Winged Subsoil	–	–	–	–	–	–

to deep tillage compared with conventional tillage on alluvial soils was more than sufficient to offset the greater additional total expenses associated with deep tillage treatments. Sensitivity analysis showed that deep tillage offered significant reductions in financial risk compared with conventional tillage because the output price could drop to lower levels and still yield positive net returns above the total specified expenses. The relative profitability of various treatments also did not change with changing input costs. A recommendation to purchase deep tillage equipment can therefore be made on the basis of both increased profitability and reduced exposure to output price risk.

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